Chapter 1: Fundamentals

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- What is GIS
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(*please note that source references presented refer to everything between the current reference and the previous reference*)

What is a Map?

A map is any representation of a geographic area – that is, a part or all of the earth's surface. That surface usually contains many things that the map-maker wants us to see in one image, for example, roads, cities, and lakes. Maps above all help us to graphically display spatial relationships. By using a map, we can show the relationship between one feature -- such as a mountain -- to others, such as rivers or cities. Maps can depict many types of phenomena in the encounter between people and place. They may reveal natural encounters as people represent the physical environment, cultural encounters as they show where two or more groups of people interact, political encounters as two or more nations come in contact, and technological encounters as a result of humankind's ingenuity in developing transportation systems, agricultural areas, and mining locations.

(*From http://libraries.uta.edu/ccon/whatis.shtm*)

Projections

The earth is a somewhat lumpy spheroid (sphere-like) shape, not a flat plane. Map **projections** are attempts to portray the surface of the earth, or a portion of the earth, on a flat surface. If we were to place a light bulb inside a translucent globe and project the image onto a wall - we'd have a map projection. However, instead of projecting a light, cartographers use mathematical formulas to create projections.
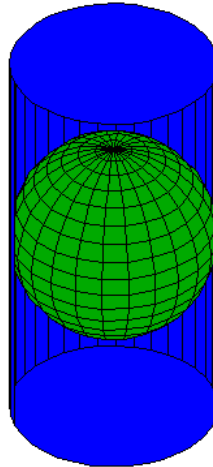
Cylindrical Projection Surface

Some distortions of conformality (shape), distance, direction, scale, and area always result from this process. You've probably seen maps of the world that show Russia, Greenland and northern Canada as much larger than they really are. Some projections minimize distortions in some of these properties at the expense of maximizing errors in others. Some projections are attempts to only moderately distort all of these properties.

(*Adapted from: Peter H. Dana, The Geographer's Craft Project, Department of Geography, The University of Colorado at Boulder http://www.colorado.edu /geography/gcraft/notes/mapproj/mapproj.html*)

Coordinate Systems

Once map data are projected onto a planar surface, features must be referenced by a planar coordinate system. The geographic system (latitude-longitude), which is based on angles measured on a sphere, is not valid for measurements on a plane. Therefore, a Cartesian coordinate system is used, where the origin (0, 0) is toward the lower left of the planar section. The true origin point (0, 0) may or may not be in the proximity of the map data you are using.

(*Copyright © Phil Hurvitz, 1998-2004, http://gis.washington.edu/esrm250/lessons/ projection/#coord_systems*)

(*Image from: http://www.colorado.edu/geography/gcraft/notes/coordsys/coordsys.html*)
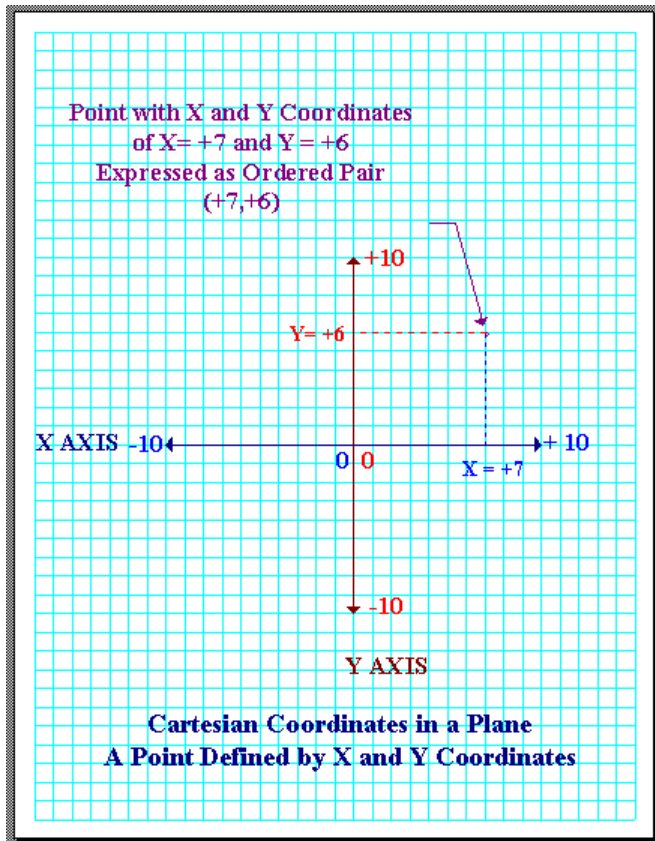
In some parts of the United States, the State Plane coordinate system (which is alternatively abbreviated as *SPS* or *SPCS*) is extremely popular among state and local governments. Its popularity is primarily due to its accuracy -- in terms of linear measurements, it's four times as accurate as the Universal Transverse Mercator (UTM) system.

(*From: http://welcome.warnercnr.colostate.edu/class_info/nr502/lg3/*
*datums_coordinates/spcs.ht*ml)

Datums

Geodetic datums define the reference systems that describe the size and shape of the earth (remember, the earth is a spheroid rather than a true sphere). Hundreds of different datums have been used to frame position descriptions since the first estimates of the earth's size were made by Aristotle. Datums have evolved from those describing a spherical earth to ellipsoidal models derived from years of satellite measurements.

Referencing geodetic coordinates to the wrong datum can result in position errors of hundreds of meters. Different nations and agencies use different datums as the basis for coordinate systems used to identify positions in geographic information systems, precise positioning systems, and navigation systems. The diversity of datums in use today and

Intro to GIS, VT Geo. Data, and QGIS (2012)

the technological advancements that have made possible global positioning measurements with sub-meter accuracies requires careful datum selection and careful conversion between coordinates in different datums.

(*Adapted From: Peter H. Dana, The Geographer's Craft Project, Department of Geography, The University of Colorado at Boulder http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj.html)*
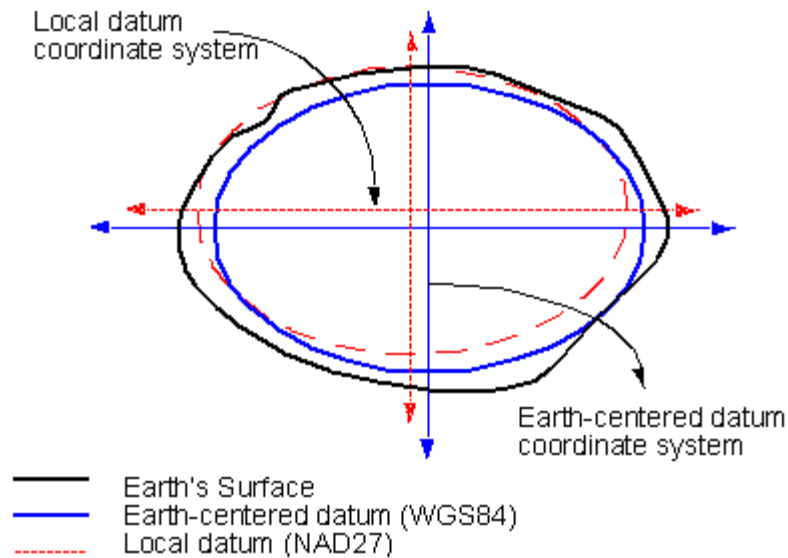
(Image found at http://gis.washington.edu/esrm250/lessons/projection/#datums , cited as "Image from ESRI")

Creating a Flat Map from a "Globe" Exercise

1. Draw some continents on the clear acrylic sphere provided to you (use Vis-a-Vis transparency markers or dry-erase markers, or tape some shapes on the spheres).

2. Discuss within your group how you can most accurately transfer the location and shape of the continents (and their relationship to one another!) from the Globe to paper.

http://earth.rice.edu/mtpe/geo/geosphere/topics/mapprojections.html
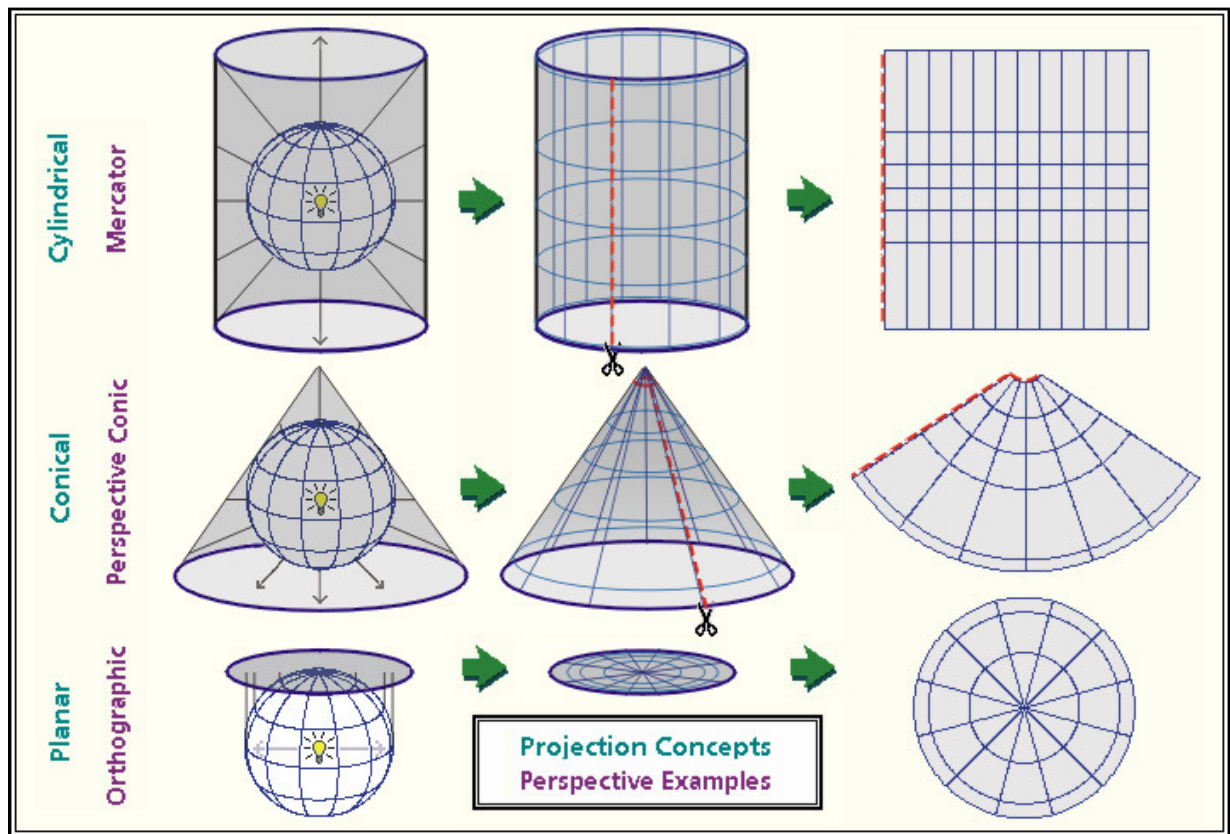
3. Do it! Consider how well it works, what "distortions" you are introducing as you move information from a sphere to a plane, whether you should have chosen a different method.

4. Share with the full class how your group approached this challenge and how well it worked, whether you would do things differently if you were to do it again.

What is GIS?

GIS stands for Geographic Information System.

The earliest GIS programs were developed simply to allow map information to be stored in computerized form. This made maps easier to store, reproduce and update. The process of capturing map information in digital form begins with the classification of all features.

Look at any map – the different shapes and symbols are used to illustrate features. There are four main types of symbol used to depict the different feature types. In fact, all map features can be divided into one of four different categories:

- **Point** (for example, a cross symbol to represent a church).
- **Line** (for example, a yellow line to represent a road).
- **Polygon shape** or **Area** (for example, a blue area to represent a lake).
- **Text** (for example, the name of a building).

The map is actually a very sophisticated information source. The human eye is able to interpret a rich amount of information from a map simply from the pictorial content. This is enhanced by the use of textual annotations (names of objects are written on a map in such a way that the letters do not get in the way of the geographical features themselves). GIS works by taking all of this information and recording it in electronic form.

How is map information translated into digital form and read by a computer? The GIS must be able to store information about:

- The **geometry:** the shape and location of the objects
- The **attributes:** the descriptive information known about the objects, normally displayed on a map through symbology and annotation.

There are two fundamental methods of storing this map information in digital form: **raster** and **vector**.
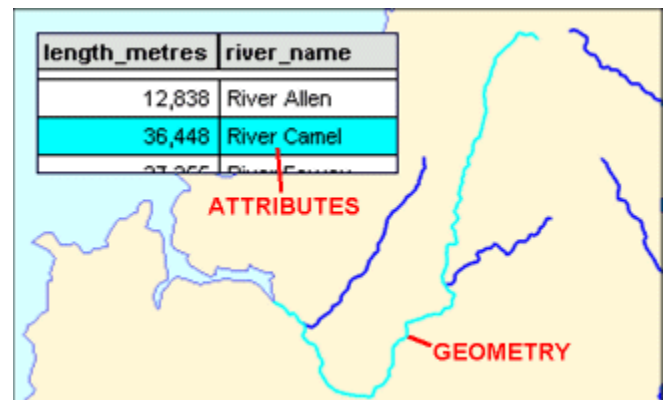
These are covered in the next section: *Introducing raster and vector*.

The first step in converting map information into a form that can be read by a computer is to describe the shapes and locations of features using a series of numbers. Computers store information in sequences of binary digits (bits), which form a code for every possible number or letter.

This fits with the way maps reference geographical locations on the earth's surface, through a system of coordinates. These *coordinate systems* can be local, national or international. All locations and shapes can be defined in terms of x and y coordinates from a given grid system: it is these numerical values which are used to translate map information into digital form. This applies in both vector and raster formats.
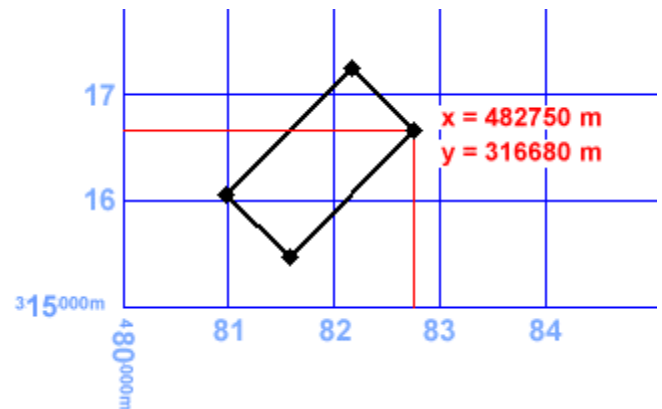

Introducing Vector and Raster

Vector data

In vector data the features are recorded one by one, with shape being defined by the numerical values of the pairs of **xy** coordinates.

- A **point** is defined by a single pair of coordinate values.
- A **line** is defined by a sequence of coordinate pairs defining the points through which the line is drawn.
- An **area** is defined in a similar way, only with the first and last points joined to make a complete enclosure.
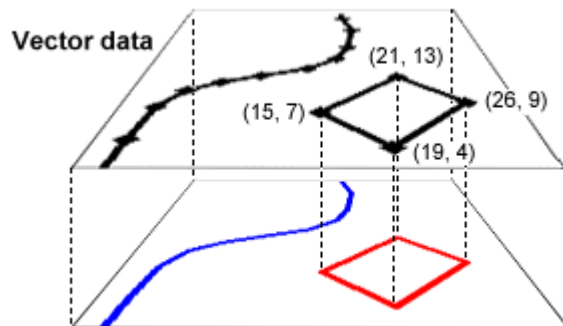

Vector data can be thought of as a list of values.

In the example above the map represents a building as a simple red rectangle. In vector data the position and shape of the building is captured as a series of four pairs of numerical coordinates. To reproduce the building in a GIS the computer reads these values and draws a line linking the coordinate positions. The vector version can also store additional context information about these features – the *attributes* – a very important aspect, which will be explained in later chapters of the GIS files.

Raster data

In raster data the entire area of the map is subdivided into a grid of tiny cells. A value is stored in each of these cells to represent the nature of whatever is present at the corresponding location on the ground. Raster data can be thought of as a matrix of values.

The major use of raster data involves storing map information as digital images, in which the cell values relate to the pixel colours of the image. In the example above the data records the colour of the feature which occupies that part of the map surface; the values recorded in the cells are either white, blue or red. To reproduce the image the computer reads each of these cell values one by one and applies them to the pixels on the screen.
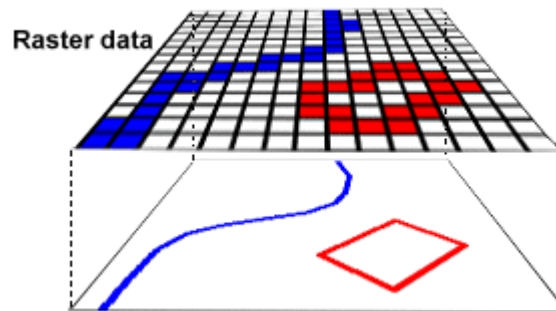
Raster data

Raster vs Vector?

Both types of data are very useful, but there are important differences; the characteristics below are broad generalisations which do not necessarily apply in all circumstances.

Vector

- relatively low data volume
- faster display
- can also store attributes
- less pleasing to the eye
- doesn't dictate how features should look in a GIS

Raster

- relatively high data volume
- slower display
- has no attribute information
- more pleasing to the eye
- inherently stores how features should look in a GIS

(From the Ordnance survey web page (great Britain's National Mapping Agency): http://www.ordnancesurvey.co.uk/oswebsite/gisfiles/section1/page3.html)

GIS Data Formats and Storage

Geographic Data Types
Shapefiles are ESRI format files that hold vector-based data. Vector data layers are points, lines (arcs, polylines), and polygons (closed shapes with defined area).

An ESRI shapefile consists of a main file, an index file, and a dBASE table. The main file is a direct access, variable-record-length file in which each record describes a shape

with a list of its vertices. In the index file, each record contains the offset of the corresponding main file record from the beginning of the main file. The dBASE table contains feature attributes with one record per feature. The one-to-one relationship between geometry and attributes is based on record number. Attribute records in the dBASE file must be in the same order as records in the main file.

Images are raster-based datasets that are made up of cells, organized in columns and rows, that contain data. Raster imagery may include digital versions of USGS quadrangle maps (Digital Raster Graphic, DRGs) and aerial photography (Digital Orthophoto Quads, DOQs).

Naming Conventions
All file names adhere to the 8.3 naming convention. The main file, the index file, and the dBASE file have the same prefix. The prefix must start with an alphanumeric character (a–Z, 0–9), followed by zero or up to seven characters (a–Z, 0–9, _, -). The suffix for the main file is .shp. The suffix for the index file is .shx. The suffix for the dBASE table is .dbf. All letters in a file name are in lower case on operating systems with case sensitive file names.

Examples
Main file: counties.shp
Index file: counties.shx
dBASE table: counties.dbf

(*Adapted From: ESRI Shapefile Technical Description: An ESRI White Paper—July 1998 http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf*)

File Management
When saving many different data layers to a server or PC, files could potentially be lost and precious time wasted looking through hundreds of documents just to find a specific file. That is why it is critical to establish a strong and clear **file structure** before work begins. You can organize digital files in digital folders, much like paper files are stored within folders in a filing cabinet.

All your folders will be created in a file structure, which is simply a system for organizing your files in a logical way. Unlike folders in a filing cabinet, which are usually organized alphabetically, you have a lot of flexibility in designing an electronic file structure. You can even create folders within folders, called subfolders, to make your file structure fit the specific needs of your uses.

Here is an example in an educational setting. Let's say the file structure is organized so that each student has his or her own folder to store digital files. The students are working on a history project about the gold rush and have been asked to create a PowerPoint presentation displaying a timeline of important events and a bibliography of their sources in Microsoft Word. Students can create a subfolder called "Gold Rush" inside their own

folder. They can store their PowerPoint presentation and Word document inside the "Gold Rush" folder, which makes those files easy to locate.
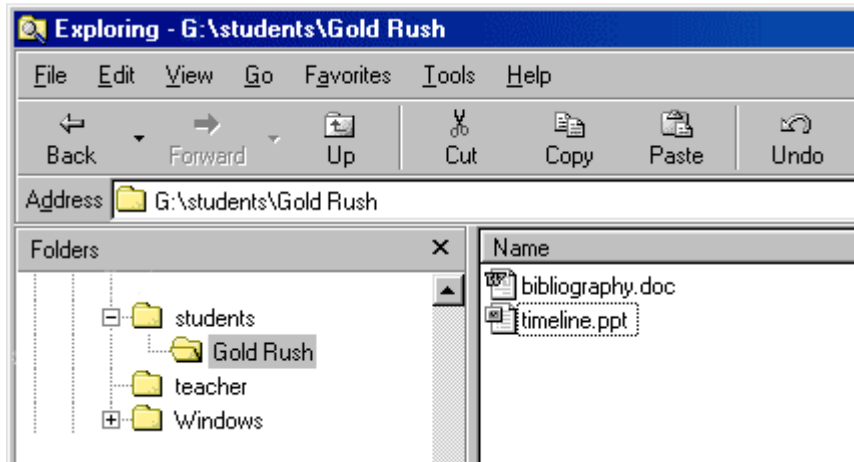
First, decide how to organize the folders according to the amount and type of computer work you and your fellow GIS-users do. You could organize your GIS related files by data theme (roads, boundaries, natural resources, parcels…) or by department (listers, clerk, public works, planning, conservation…), or any other scheme that all users agree makes sense.

(*Adapted From: http://www.thirteen.org/edonline/ntti/resources/workshops/digital_file/ practice.html#org*)